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The Changing Strategy-Technology Relationship in
Technology-Based Industries: A Comparison
of the United States and Japan

by

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and

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January 5, 1984
Revision

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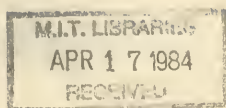
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I. The New Strategic Role of Technology

Only in this decade have we witnessed the surprisingly rapid emergence and easy acceptance of technology as a major strategic variable throughout the globe for both corporations and national governments. Our aim is to examine the managerial implications of this development using two concurrent perspectives: a cross-industry analysis of technology-strategy behavior in the semiconductor, robotics, and biotechnology industries; and a cross-country study of these industries in the two key settings, the United States and Japan. We will conclude by arguing that the current worldwide emphasis on technology is really part of the rise of what may be termed the "New Strategic Complexity" in the 1980s, the heart of which focuses on the need today to manage effectively extreme diversity along a number of dimensions and to utilize the informal and formal aspects of strategy. This new situation is extremely significant for top managers. Corporate strategy in the 1980s, at least in technology-based sectors, will demand a broader array of conceptual, structural, and implementation skills that was true for even the recent past.

II. Technology and Strategy -- The Conventional View

The fields of technology and strategy, until very recently, have generally been studied and managed as separate areas. To take technology first, this subject has been studied in considerable depth as part of R&D management and the process of technological innovation; it has been examined and reexamined as a determinant of organizational structure; and it has been seen as being a critical factor in influencing the evolution of the international product life cycle.¹

Modern technological innovation, furthermore, is now recognized as a complex activity. One important aspect of our growing understanding is the realization that technological innovation is a process, made up of diverse parts, varied participants, complicated patterns of evolution and information feedback loops, and potentially lengthy time durations. Moreover, great emphasis is now placed on the role of "market pull" and "user needs". Finally, and this point must be emphasized, important research continues to highlight the key role of people, as champions, entrepreneurs, or technology-familiar managers, in effectively promoting and accelerating innovation.² We will later return to the ever-present need for these human micro engines of change.

But one of the most significant attributes of modern technological innovation thus far has been de-emphasized: the variety of types of technological innovation that exist in modern advanced societies. In developed economies there are at least three ideal or pure "modes" of technological innovation that can be identified: Mode I - technological innovation in the small high technology firm; Mode II - technological innovation in the large, multi-product, multi-market, and multi-division corporation; and Mode III - technological innovation in huge, multi-organization enterprises that usually involve institutions from both the public and private sectors that are working together on a mission-oriented large-scale program.³ A comparison of the different modes is given in Figure 1. Each mode has distinct strengths and weaknesses. Moreover, they do not exist independently. Top managers today in technology-based sectors must often choose and blend the most appropriate mode(s) of technological innovation to establish an effective portfolio of types of innovative activities.

To turn to the field of corporate strategy, we have noted before that until recently it has largely ignored technology. In the 1960s the core of strategy thinking lay in its focus on intelligently guiding the long-term

A COMPARISON OF THE CHARACTERISTICS OF TECHNOLOGICAL INNOVATION IN THREE MODES

Key Node Attributes	Inputs				Internal Processes		Output
	Technology/ Skills Available	Environment	Market	Goal-setting	Communication System	Organisation Structure	Innovation: Product-line Process or System
MODE I *	-emphasizes exploiting -defined product -known -technologies -technological -capabilities -restricted to -few areas -key technological -skills reside in -top management	-contained & -definable	-markets for -the product -are few & -definable	-goals are set by -top management -goal-setting is -informal with few -actors involved -options open to -the firm are -few	-informal -to people -information does -not demand com- -plex system due -to few recipients	-organization -structure comprises -few sub-units -information -gets involved -in all -activities in -the organiza- -tion	-typically a -product or a -product-line -scope tends -to be limited -by the techno- -logical -capabilities -of the top -management
MODE II **	-complex, un- -defined product -or process areas -skills consists of -technological as -well as non- -technological, -like marketing, -in these areas. -Mode II is con- -cerned with -existing & non- -existing techno- -logical skills -which they help to -develop	-multiple & -complex but -still -definable	-markets for -innovations -are multi- -user markets -& complex	-innovation goals -are partially -set by formal -systems -firm has several -technological -options to -choose from -top management -may or may not -be directly -involved in -identifying or -pursuing techno- -logical options	-complex due to -several organi- -zational levels, -formal & -informal -affecting commu- -nication & -possible but -difficult to -achieve	-organization -tends to be -complex, -divided into -product groups, -divisions, etc. -often different -sub-units have -conflicting -activities & -priorities -corporate bound- -aries are -definable	-large market -and/or -complex -products & -processes
MODE III ***	-diverse techno- -logical skills -existing & non- -existing are -needed -diverse non- -technological -skills are also -needed	-complex, -constantly -changing, & -hard to -define -difficult to -distinguish -at times -between -internal -processes, -the environ- -ment, & the -market	-the market -for the -innovation -consists of -several -audiences - -those -interested -in technical -aspects, -others in -information -regarding -its impact, -skill -others in -funding etc.	-goal-setting is -a very -fragmented, -political, & -visible -process -total communica- -tion is almost -impossible -communication -must address -multiple -cultures, & -cater to the -needs of -multiple -organizations -formal systems are -not usually -effective & so -communication -cuts across -organizational -boundaries	-complex -in definite -boundaries -different -functions are -assigned to -different -divisions -eg funding -organisations -multiple -overall manage- -ment (Agency) -R&D (labora- -tories) - manu- -facturing -(contractors) -organization in -charge of distribu- -tion -this Mode can be -temporary if not in- -tended with implementa-	-either a -large, -single -product, -prototype, -or complex -systems -involving -multiple -organizations -& technology	

*(Technological Innovation process in small, high-technology firms.)

** (Technological innovation in large multiproduct, multimarket, and/or multidivisionalized corporations,)

*** (Technological innovation process in multi-organization and usually multi-sector settings.)

direction of the whole enterprise and on the effective qualities of leadership for accomplishing that task. Very quickly, the major matter of concern for strategy theorists and practitioners became issue of guiding the large, diversified corporation. There was also in the 1960s a particular fascination with designing appropriate internal structures and reward, control, and information systems for supporting overall strategy in order to maximize business opportunities and minimize the possibility of failure.

Toward the end of the 1960s and throughout the 1970s corporate strategy became increasingly analytical and formal, incorporating some of the insights and methodologies of such fields as regional economics, finance, micro-economics, statistics, and industrial organization theory. Such formal strategic planning approaches include the strategic portfolio as developed by the Boston Consulting Group, Arthur D. Little, McKinsey and Company, and others, regression analysis using a large SBU-level data based called PIMS, and industry competitive analysis. The new strategic planning methods dealt particularly with the problems of formatting the product-market diversity of increasingly complex corporations and, varying degrees of effectiveness, gave senior managers in these organizations a framework for strategically allocating resources in the face of increasing variety.⁴ The incredible rise and success of strategic consulting firms in the late 1960s and 1970s and the widespread acceptance of strategic portfolio methods testify to the real need by senior managers for such analytical approaches in modern multi-product/market and increasingly global corporations.⁵

By the end of the 1970s, therefore, in a conceptual sense an important dichotomy had become evident in the strategy field. On the one hand, successful strategy was seen to depend on the informal, ambiguous, and hard-to-define qualities of good leadership capability, the sound instincts of senior managers, skilled implementation skills, and line experience, as well as on

appropriate structures and systems within an organization. We may term these characteristics Implicit Strategy. On the other hand, successful strategy was also said to require a careful, formal assessment of the corporation's competitive environment using analytical approaches and good staff work. We may term these features of strategy Explicit Strategy.

During the 1970s Explicit Strategy became very popular in the United States. But by the 1980s, the pressure of an increasingly hostile economic and competitive environment, the business success of the Japanese in several fields without the apparent help of formal strategic planning or consulting firms, and a severe economic recession, all triggered a reaction against a total emphasis on Explicit Strategy thinking and methods. Critics lambasted Explicit Strategy's emphasis on staff, planning, formulation, and a neglect of true expertise. They called for a kind of return to good line management skills, implementation, and substantive knowledge of the technology, operations, and market of a business -- in effect to the values and practices of Implicit Strategy.⁶

We will return later to this apparent dichotomy in corporate strategy between Implicit and Explicit perspectives. For the moment, we would only like to comment that these two perspectives do not to us seem mutually exclusive and that, as we hope to demonstrate, the New Strategic Complexity requires competence with both approaches. Indeed, in modern technology-based sectors the need for effective Implicit and Explicit is absolutely essentially for long-term success.

III. Technology and Strategy Merged

We are ready conceptually to incorporate technology and on corporate strategy --two subjects that have traditionally been studied and managed as distinct fields-- into a single framework.⁷ This is an important step, because today technology is an increasingly important part of high-level

decision making in modern corporations, especially in technology-based sectors. Also, the continuing tension and key tradeoff between Implicit and Explicit perspectives in modern corporate strategy is highlighted when technology becomes a significant strategic variable.

As seen in Figure 2, technology and corporate strategy can be related in either a disjointed or a linked fashion. A disjointed set of relationships indicates that relevant activities are being done in separate units or organizations with few formal connections and with little overall strategic direction or coordination. A linked set of relationships indicates that most relevant activities are usually formally connected and under some sort of conscious strategic direction or coordination.

There are at least four kinds of linkages: intraorganizational, domestic interorganizational, multinational interorganizational, and private-sector-public-sector. All such linkages are becoming more important and more managed as the various modes of technological innovation, by design, increasingly overlap and interrelate. For example, many Mode II institutions are now attempting to gain the benefits of the successful Mode I firm, such as an entrepreneurial spirit, a dedicated set of champions, a drive to be close to the market and to users, and a familiarity with the relevant technology and products at the highest decision-making levels. To achieve these ends, top management is employing such intraorganizational linkage mechanisms as extreme decentralization (such as at 3M), a matrix-type organizational structure based on long-term and short-term criteria (such as OST at Texas Instruments), and new venture groups (such as Exxon Enterprises).⁸ Similarly, an array of interorganizational linkages, both wholly domestic and multinational, have emerged in the form of joint ventures, research contracts, equity relationships, and licensing or marketing agreements. Indeed, as has been pointed out elsewhere, earlier notions of a pure international product life cycle model now need major revision.⁹

Figure 2

Overall Conceptual Framework:
The Technology-Strategy Relationship

Forms of Technological
Innovation

Mode I
Mode II
Mode III

Strategic Management

<u>Implicit</u>	<u>Explicit</u>
<u>Informal</u>	<u>Formal</u>
Implementation	Formulation
Line	Staff
Action	Analysis

Disjointed

Linked

Distinctly Separate Centers Activity

Autonomy

Various Modes Remain Separate

Forms of Linkages

Intraorganizational

Interorganizational-Domestic

Interorganizational-Multinational

Public-Private

Various Modes are Consciously

Connected and Coordinated

Direction of Evolution 1960-1980 : "New Strategic
Complexity"



Finally, in the realm of Mode III, there has been a significant change in the past two decades. In the 1950s and early 1960s, at least in the United States, large-scale government programs that also involved private firms and other institutions were concentrated in the defense and aerospace sectors where government was the primary buyer as well as funding source. In the 1960s and 1970s large-scale programs entered new sectors, such as energy and transportation, for ultimately private-sector commercialization objectives. Currently, under the rubric of national industrial policy, there is renewed interest in how the government can help trigger significant innovation. This, of course, is due partially to the importance and apparent success, especially in Japan, of large-scale, planned innovation. Indeed, the current conceptual connections between Mode II and III are often quite direct. A fascinating and illuminating development, starting in the mid-1970s, has been the effort to apply formal strategic analytical approaches to a whole economy for making industrial public policy. This methodology has been attempted for Britain, Sweden, and even recently the state of Rhode Island.¹⁰ Several other nations are also at least partially moving in this direction, and advocates of similar approaches for the United States are proliferating.¹¹

The framework presented underscores a few fundamental and general aspects of modern strategic decision making. First, as strategy itself becomes more Explicit, with managers attempting to attack the task of understanding and managing an increasingly larger part of an increasingly more complex environment, the burden on Explicit Strategy grows. Second, in the face of all this complexity, which requires even more formal analysis, the other side of strategy, the Implicit side, unfortunately tends to receive less attention. Implicit Strategy, with its focus on people, implementation, ambiguity, structure and systems, and instinct, often seems less important than formal strategic planning and less visible and to be even more difficult to maintain

in good working condition. A key challenge, therefore, for modern corporate strategy is to nurture effectively Implicit Strategy behavior while also developing relevant Explicit Strategy approaches. Finally, the framework helps highlight the reality of the New Strategic Complexity. We can now see, for example, that strategy is truly global; that it involves the simultaneous management of different kinds of organizations, markets, products, and technologies; and that it can include both effective competition and imaginative cooperation through the building of relevant linkages. We will now apply this framework to three sectors in two countries.

IV. Comparative Analysis: The Semiconductor, Robotics and Biotechnology Sectors in the United States and Japan

A major objective of our cross-sectoral and cross-country comparisons will be to see how well we can identify the merging of technology and corporate strategy and the rise of the general New Strategic Complexity in both the United States and Japan. Consequently, we will focus especially on three characteristics for each of the sectors reviewed: the composition of the modes of technological innovation, the degree of Implicit and Explicit Strategy that exist, and the pattern of and management of linkages that can be identified. If a more or less unifying pattern can be found, across two obviously very different advanced nations and three technology-based sectors with different scientific foundations, different industrial organization characteristics, and different histories and life-cycles, then we will feel confident that we can make some useful generalizations about the direction and state of modern technology-strategy issues.

A. Semiconductors

The U.S. and Japanese semiconductor industries are particularly relevant to examine for our purposes. The rise of semiconductors in the 1950s and early

1960s has left an indelible mark on our thinking about technology-based sectors and innovation theory. In fact, the early semiconductor industry represents the prototypical disjointed technology-strategy relationship.¹² There was at that time rapid growth and rampant innovation by a diverse array of numerous firms. The industry exemplified the traditional international-product-life-cycle and international-diffusion-of-technology models by clearly beginning in a single advanced nation, the United States, and then spreading abroad as the industry matured and grew. The corporate demography of the early semiconductor industry also exhibited dramatic and memorable patterns. Most old-line vacuum tube manufacturers failed to make the transition to semiconductors. Several kinds of new entrants succeeded in dominating the new industry. Indeed, one is struck by the variety, birth, growth, and death of firms in the early semiconductor industry and by, in the end, the dominant market share of the new firms. There was also relatively easy access in these early years to the critical resources of skilled people, venture capital, and technology, especially via the well-known interfirm movement of committed and knowledgeable entrepreneurs. Finally, government played a key role in stimulating early demand. But basically the government's role, through the Defense Department and NASA, was as an initial market, not as a direct shaper of industry behavior or structure via national-industrial-policy mechanisms.¹³ In these early years, the various modes of technological innovation were separate; strategy was more or less implicit; and the linkages were highly disjointed.

But the U.S. semiconductor industry today has a very different kind of structure and set of business patterns. First of all, as seen in Figure 3, Mode II is at least as important as Mode I. Large established corporations are perhaps the major participants in this industry. Second, the linkages between the firms and various modes are increasingly numerous and complex. This characteristic is indicated by Table 1, which documents the extent of

Figure 3

U.S. Semiconductor Industry in the Early 1980s Classified
by Modes of Technological Innovation

Mode I

Numerous Small Semiconductor Companies

Mode II

IBM

Western Electric (AT&T)

Texas Instruments

Motorola

National Semiconductor

Intel

Fairchild (Schlumberger)

Signetics (U.S. Philips Trust)

Mostek (United Technologies)

RCA

Harris

Table 1

CORPORATE INVESTMENTS IN U.S. SEMICONDUCTOR COMPANIES

U.S. Semiconductor Company	Corporate Investor	Percent Ownership ^a	National Base
Advanced Micro Devices	Siemens	(20%)	West Germany
American Microsystems	Robert Bosch	(12.5%)	West Germany
	Borg Warner	(12.5%)	United States
Analog Devices	Standard Oil of Indiana		United States
Electronic Arrays	Nippon Electric		Japan
Exar	Toyo	(53%)	Japan
Fairchild Camera	Schlumberger		Netherlands Antilles
Frontier	Commodore International		Bahamas
Inmos	National Enterprise Board		United Kingdom
Interdesign	Ferranti		United Kingdom
Intersil	Northern Telecom	(24%)	Canada
Litronix	Siemens		West Germany
Maruman IC	Toshiba		Japan
Micropower Systems	Seiko		Japan
Monolithic Memories	Northern Telecom	(12.4%)	Canada
MOS Technology	Commodore International		Bahamas
Mostek	United Technologies		United States
Precision Monolithics	Bourns		United States
SEMI, Inc.	General Tel. & Elec.		United States
Semtech	Signal Companies	(merger)	United States
Singetics	Philips	(13.7%)	Netherlands
Intel	IBM		United States

Siliconix	Electronic Engr. of Calif.		United States
	Lucas Industries	(24%)	United Kingdom
Solid State Scientific	VDO Adolf Schindling	(25%)	West Germany
Spectronics	Honeywell		United States
Supertex	Investment Group		Hong Kong
Synertek	Honeywell		United States
Unitrode	Signal Companies		United States
Western Digital	Emerson Electric		United States
Zilog	Exxon		United States

SOURCES: Morgan Stanley Electronics Letter, December 31, 1979.

Dataquest, Inc., January 1979, for percent of ownership.

The consulting group BA Asia Ltd., 1980 for Maruman IC data.

Wall Street Journal, August 17, 1983, p. 10.

a No percentage indicates 100 percent (wholly owned), or presumed to be wholly owned, in the absence of data.

b Purchased in 1980 from Mansei KK, pending litigation.

U.S. Congress, Joint Economic Committee, International Competition in Advanced Industrial Sectors: Trade and Development in the Semiconductor Industry, A Study Prepared for the Joint Economic Committee (Washington, D.C.: U.S. Government Printing Office, February 18, 1982), pp. 40, 41.

non-internal corporate investment in the U.S. semiconductor industry. Clearly, the linkages --both domestic and international-- between Mode I and Mode II firms and between various Mode II firms-- are increasing and becoming an important part of corporate strategy in the U.S. semiconductor industry.

A fascinating example of this trend is IBM's equity investment in the leading state-of-the-art semiconductor company, Intel. In December, 1982, IBM announced that it would buy a 12-percent stake in Intel for \$250, which it did in February, 1983. Later, in August, 1983, IBM boosted its position in Intel to about 13.7 percent. Most observers believed IBM was doing more than making a good financial investment. Rather, IBM appeared to be taking strategic action to protect its and America's technological base by strengthening a key U.S. innovator in semiconductors. IBM had no intention of letting the U.S. lose semiconductors as the country had lost, say, consumer electronics. Furthermore, Intel was already a key outside supplier to IBM, with IBM accounting for about 13 percent of Intel's 1981 revenue.¹⁴

The spectacular rise of the Japanese semiconductor industry, along with such other key Japanese industries as shipbuilding, steel, automobiles, and consumer electronics, is obviously one of the major economic and technological success stories of the postwar period. The incredible growth of this industry is seen in Table 2. But just as striking for our purposes, as seen in Figure 4, is the profile of modes of technological innovative activity in the Japanese semiconductor industry. Unlike its U.S. counterpart, which focuses on Modes I and II, the Japanese activities are almost exclusively in very large firms and major business-government-development programs, in other words Modes II and III. Moreover, as seen in Table 3, the major Japanese producers of semiconductors are large multiproduct and multimarket corporations that produce electronic products that utilize systems of integrated circuits for the consumer electronics, computer, and telecommunications end markets. The

Table 2
Output of Semiconductor in Japan

Production of Semiconductors
(Y million)

Years	Linear		Bipolar-Digital		MOS		Total	
	Production	Growth Rate	Production	Growth Rate	Production	Growth Rate	Production	Growth Rate
1971	9,096	-	18,951	-	15,144	-	43,191	-
1972	19,382	13.1%	15,117	20.2%	24,470	61.6%	58,969	36.5%
1973	27,276	40.7	24,586	62.6	42,773	74.8	94,635	60.5
1974	31,601	15.8	31,399	27.7	46,893	9.6	109,893	16.1
1975	27,098	14.2	22,343	28.8	55,305	17.9	104,746	4.7
1976	58,900	117.4	31,561	41.3	85,756	55.1	176,217	68.2
1977	64,802	10.0	35,464	12.4	84,967	0.9	185,233	5.1
1978	79,114	22.1	40,920	15.5	131,656	54.9	251,690	35.9
1979	95,774	21.1	51,101	24.9	196,327	49.1	343,202	36.4
1980	133,337	39.2	72,630	42.1	309,657	57.7	515,624	50.2
1981	187,825	40.9	94,284	29.8	339,856	9.7	621,965	20.6
Average Growth Rate		40.57		20.73		38.95		32.48

Source: Akimitsu Sakuma, "Nihon Kigyo no Kenkyu (Research and Development in Japanese Firms)," *Business Review*, Vol. 30, NO. 3-4, March, 1983, p. 122 (The actual data was provided by MITI).

Figure 4

Modes of Technological Innovation in the Japanese
Semiconductor Industry in the Early 1980s

Mode I

Mode II NEC

Hitachi

Toshiba

Fujitsu

Sharp

Matsushita Electric

Mitsubishi Electric

Tokyo Sanyo

Okai Electric

Sony

Fuji Electric

Mode III VLSI Development (1976-1979)

Opto - IC Development (1981-1991)



Table 3

Percentage of Total Sales for Major Japanese Semiconductor
Producers in 1979 Accounted for by Semiconductor
Sales (in Comparison With a Sample of Representative U.S.
Merchant Firms)

<u>Japanese Firms</u>		<u>U.S. Firms</u>	
NEC	17.8%	AMD	89%
Fujitsu	6.7%	Fairchild	69%
Toshiba	5.5%	Intel	75%
Hitachi	4.1%	Mostek	93%
Mitsubishi	3.8%	Motorola	31%
Matsushita	2.3%	National	85%
		Texas Inst.	36%

Source: U.S. Congress, Joint Economic Committee, International Competition in
Advanced Industrial Sectors: Trade and Development in the Semiconductor
Industry, A Study Prepared for the Joint Economic Committee (Washington,
D.C.: U.S. Government Printing Office, February 18, 1982), p. 64.



semiconductor market is strategically not the only important end market for these firms. The higher value-added markets of systems products are also critical.¹⁵ In the U.S., on the other hand, merchant semiconductor firms like Texas Instruments, National Semiconductor, and Motorola, are major participants.

Developing state-of-the-art technology is an essential part of strategy in the Japanese semiconductor firms. These firms generally are not solely applying the traditional Japanese strategic approach of stressing long-term growth and seeking dominant market share through volume production, low costs, and quality — practices associated with Japanese success in steel, automobiles, and consumer electronics. World market share figures for integrated circuits, as seen in Table 4, show only a very slight growth for the Japanese in recent years. Instead, the Japanese firms are clearly using and developing their semiconductor capability, such as in the 64K RAM and the 256K RAM chips, to help for competing in the related consumer electronics, computers, and telecommunications industries as well as to compete in the semiconductor industry itself. Semiconductor technology is now a broad strategic weapon in related valued-added sectors as well as in the component semiconductor market for these Japanese firms.

The strategic development of semiconductor technology and Explicit Strategic patterns are seen even more clearly in Japanese Mode III behavior for semiconductors. The Very Large Scale Integrate Circuit (VLSI) Project, which lasted from 1976 to 1980, is one of the most successful and well-known examples of national industrial policy for developing new and important technology. The VLSI Project was sponsored by MITI and the Very Large Scale Integrated Technology Research Association, which was established by MITI to oversee this project. MITI had chosen its target area carefully and intelligently. MITI correctly perceived that VLSI circuits were the next generation of

Table 4

WORLD IC PRODUCTION

(millions of dollars)

(Percentages in Paratheses are of Total World Market Share)

Producing Region	1978 ^a	1979 ^b	1980 ^c	1981 ^d
U.S.				
IC Merchant	3,238 (46%)	4,071 (45%)	6,360 (49%)	7,000 (48%)
IC Captive	1,344 (20%)	2,010 (22%)	2,695 (21%)	3,050 (21%)
IC Total U.S.	4,582 (66%)	6,081 (67%)	9,055 (70%)	10,050 (69%)
Western Europe				
IC Total	453 (69%)	600 (7%)	710 (5%)	765 (5%)
Japan				
IC Total	1,195 (17%)	1,750 (19%)	2,580 (19%)	2,970 (20%)
Rest of World				
IC Total	782 (11%)	675 (7%)	740 (6%)	835 (6%)
Total ICs	7,012 (100%)	9,106 (100%)	13,085 (100%)	14,620 (100%)

SOURCE: a) ICE, STATUS 1980, p. 4.
b) ICE, STATUS 1981, p. 2.
c) Figures after November 1980 estimated
d) Estimated for year

U.S. Congress, Joint Economic Committee, International Competition in Advanced Industrial Sectors: Trade and Development in the Semiconductor Industry, A Study Prepared for the Joint Economic Committee (Washington, D.C.: U.S. Government Printing Office, February 18, 1982), p. 123.

semiconductors and would enable manufacturers to build smaller and more reliable computers and many other electronic products.

The VSLI Project was unique for Japan at that time since it was a truly high-technology oriented enterprise. Like most Mode III endeavors it had both public and private components and the participants on the private side were all intensely competitive semiconductor manufacturing companies: Fujitsu, Hitachi, Mitsubishi Electric, Nippon Electric Co. (NEC), and Toshiba. These firms had different interests, priorities, and expectations. But through skillful management on a host of dimensions the project had succeeded by 1980.¹⁶ The success of the project served as a model for Japan and helped accelerate the development of other new creative technologies. Subsequent national projects --such as the Fifth-Generation Computer Project, the Optical Measurement and Control System Project, and the Flexible Manufacturing System Project-- are no longer aimed at catching up with foreign advanced technology, but at developing new technologies and products and through original, creative research.¹⁷ All these projects have been modeled after the Mode III organizational principles adopted by the VLSI Technology Research Association. The VSLI Project, thus, was a milestone in overall Japanese technology strategy.

The final point that we wish to make about the Japanese semiconductor industry is that the linkages, already in stark evidence in the VSLI Project and in later MITI-sponsored efforts, have expanded and have even become international. As seen in Table 5, many of the major Japanese semiconductor manufacturers have acquired or built manufacturing facilities in the United States and Europe. In the United States, the new facilities ultimately will all be state-of-the-art plants aimed at producing 64K RAM chips.¹⁸ As noted for the U.S. industry, though not to the same degree, the top Japanese producers are expanding beyond the home country. More important, this strategy

Table 5

5A American Subsidiaries of Japanese Semiconductor Manufacturers

Japanese manufacturer	Name of subsidiary	Location	Capital (millions of	Time of establishment
Hitachi, Ltd.	Hitachi Semiconductor American	Dallas, Texas	0.45	May 1978
Nippon Electric Co.	Electronic Arrays	Mountain View, California	7.0	December 1976 (Acquired)
Fujitsu Limited	Fujitsu Micro-electronics	San Diego, California	15.0	August 1979
Toshiba Corporation	Toshiba Semi-conductors (Maruman Integrated Circuits)	Sunnyvale, California	2.7	April 1980 (Acquired)

Data: Electronics Industry Annual Report, 1981.

5B European Subsidiaries of Japanese Semiconductor Manufacturers

Japanese manufacturer	Name of subsidiary	Location	Capital (millions of yen)	Time of establishment	Operation commencement
Nippon Electric Co.	NEC Ireland	Ireland	800	July 1974	April 1976
Nippon Electric Co.	NEC Semiconductors U.K.	U.K.	Not decided	December 1980	April 1982
Hitachi Ltd.	Hitachi Semiconductors (Europe)	West Germany	1,240	April 1980	December 1980
Fujitsu Limited	Fujitsu Microelectronics Ireland	Ireland	650	September 1980	February 1981

Data: Nihon Keiza Shimbunsha

SOURCE: The Long-Term Credit Bank of Japan, Ltd., Japan's High Technology Industries, LTCB Research Special Issue, May, 1983, p. 15.

is Explicit. These firms view semiconductors not just as a component to sell, but also as one of the building blocks for their strategies in the related and higher-value-added electronic systems industries, such as computers and telecommunications.

In both the U.S. and Japanese semiconductor industries a complex set of modes of technological innovation are at work. But in the U.S., the modes are largely I and II, the small and large firms; while in Japan they are Modes II and III, the large producers and the public-private projects. Also in both industries the strategies are increasingly Explicit. But in the U.S. the Explicit Strategy involves an increasing number of acquisitions, mergers, equity investments, and joint ventures; while in Japan it involves the use of semiconductors by large vertically integrated firms as building blocks to enter related, higher value-added industries and large, multi-member, government projects. Finally, in both, we have witnessed the rise of a linked strategy-technology relationship, which is a dramatic change from the disjointed context of the early U.S. semiconductor industry. In Japan, the linked nature of strategy and technology is even more pronounced, not just because of the multi-industry strategy of the vertically integrated firms but also due to the targeted and cooperative public-private technology development policies sponsored by MITI, exemplified by the VSLI Project.

B. The Robotics Industry

The emergence of a true robotics industry is another major development in the technology-strategy area. Here the role and success of the Japanese is even more striking than in that of semiconductors. In semiconductors, there is now perhaps a kind of dynamic balance and parity between the U.S. and Japan. In robotics, we see a U.S. industry that never took off in its early years and a Japanese industry that has already assumed global dominance and is ready to explode.

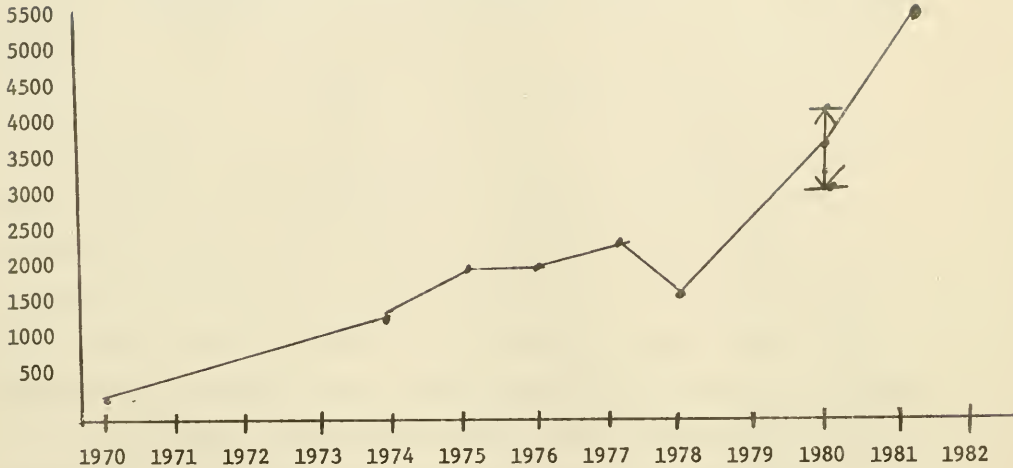
Actually, the rise of robotics is really part of a massive general restructuring of the manufacturing process and technology field. If this overall field can be thought of as kind of mega-industry, then robots, like flexible manufacturing systems, factory automation systems, and stand-alone machine tools, can be considered one of several large "strategic groups" that make up this industry.¹⁹

In the United States an understanding of this larger context is important for examining robotics. What was once a traditionally fragmented field, comprised of many small firms and few larger ones producing a so-called mature product, the machine tool, is being transformed by two key and related pressures: technological change and intense international competition. The new technologies of electronics, information software, and new materials (especially composites and powdered metals) are changing the whole character of metal fabrication, with the rise of robotics being just part of this overall change. In addition, the increasing international competition on the basis of cost and quality, especially from Japan, has profoundly shaken the traditional U.S. machine tool industry. Finally, these changes have led to a number of joint ventures and new entrants, including pure high technology robotics firms like Automatix, firms with substantial internal manufacturing requirements like General Electric or Westinghouse, computer firms like IBM, mergers or acquisitions like Westinghouse buying Unimation, and joint ventures like General Motors teaming up with the Japanese robot maker, Fanuc.²⁰

To focus specifically on robotics, we find a global technology-based industry on the verge of a probable takeoff. Figure 5 shows that at some point in the early 1980s the rate of growth of the U.S. industry began to increase significantly. But the United States is clearly behind. This is a somewhat unique situation. In semiconductors, the U.S. still dominates, in spite of a strong Japanese challenge. As we will see, in biotechnology the U.S. is clearly still ahead. In robotics, however, the United States is lagging. Why?

Figure 5

ESTIMATES OF U.S. ROBOT POPULATION 1970-1981



Point	# of Robots	Date	Source
A	200	1970 (April)	Engelberger, First National Symposium on Industrial Robots , 1970
B	1200	1974 (Dec.)	Frost and Sullivan, U.S. Industrial Robot Market, 1974
C	2000	1975 (Dec.)	Frost and Sullivan, The Industrial Robot Market in Europe, 1975
D	2000	1976 (Dec.)	Eikonix Technology Assessment, 1979
E	2400	1977 (Dec.)	Eikonix Technology Assessment, 1979
F	1600	1978 (Dec.)	American Machinist 12th Inventory, 1978
G	3000	1980 (Jan.)	Walt Weisel, Prab Conveyors
H	3500	1980 (June)	<u>Business Week</u> , Verfied by Cincinnati Milacron
I	3200	1980 (Dec.)	General Motors Technical Staff, (Bache, Shields estimate)
J	4000	1980 (Dec.)	Walt Weisel, Prab Conveyors
K	5500	1981 (Dec.)	Seiko Inc., Marketing Dept.

SOURCE: Ayres & Miller, 1982
David Schatz, The Strategic Evolution of the Robotics Industry,
Unpublished Master's Thesis, Sloan School, MIT, May, 1983, p. 88

As seen in Figure 6, the U.S. has a relatively long history of robotics research and entrepreneurship. But the structure of the U.S. robotics industry, unlike semiconductors or biotechnology, failed to evolve fast enough into a rich, diverse network of technologically innovative activities and participants. As seen in Figure 7, until very recently practically all robotics activity in the U.S. was concentrated in a few companies, with two firms, Unimation and Cincinnati Milacron, together accounting for over a 50-percent U.S. market share through 1982. Robotics in the U.S. was in the industrial R&D backwater and, except for Cincinnati Milacron, was largely a Mode I activity until the 1980s. The involvement of large manufacturing enterprises and corporations with strong capabilities in the key technologies and often huge captive markets was practically non-existent until the 1980s. Furthermore, the U.S. government, the realm of Mode III, did very little to promote robotics R&D.* The whole American effort to develop robotics until about 1980 was fragmented, limited to a few players, and lacked the support of crucial stakeholders, such the large industrial concerns and the government.

By 1980, however, the situation was beginning to change. The growth rate of U.S. robotic sales was accelerating and, just as significant, a whole set of new entrants had appeared. The new entrants, as seen in Table 6, are not primarily new start-up ventures. Instead, they represent large established enterprises with strong manufacturing and/or technological skills. Modes I and II are now fully represented. In addition, as seen in Figure 8, suddenly a whole, rich array of linkages are being established through licensing agreements, joint ventures, and mergers and acquisitions, many of which are inter-

*This contrasts, by the way, with the crucial role of the U.S. Air Force in an earlier era for developing numerically controlled machine tools, one of the most significant innovations in the history of manufacturing technologies.

Figure 6

CHRONOLOGY OF ENTRANCE INTO THE ROBOT INDUSTRY
(symbol in parenthesis indicates Mode of innovation)

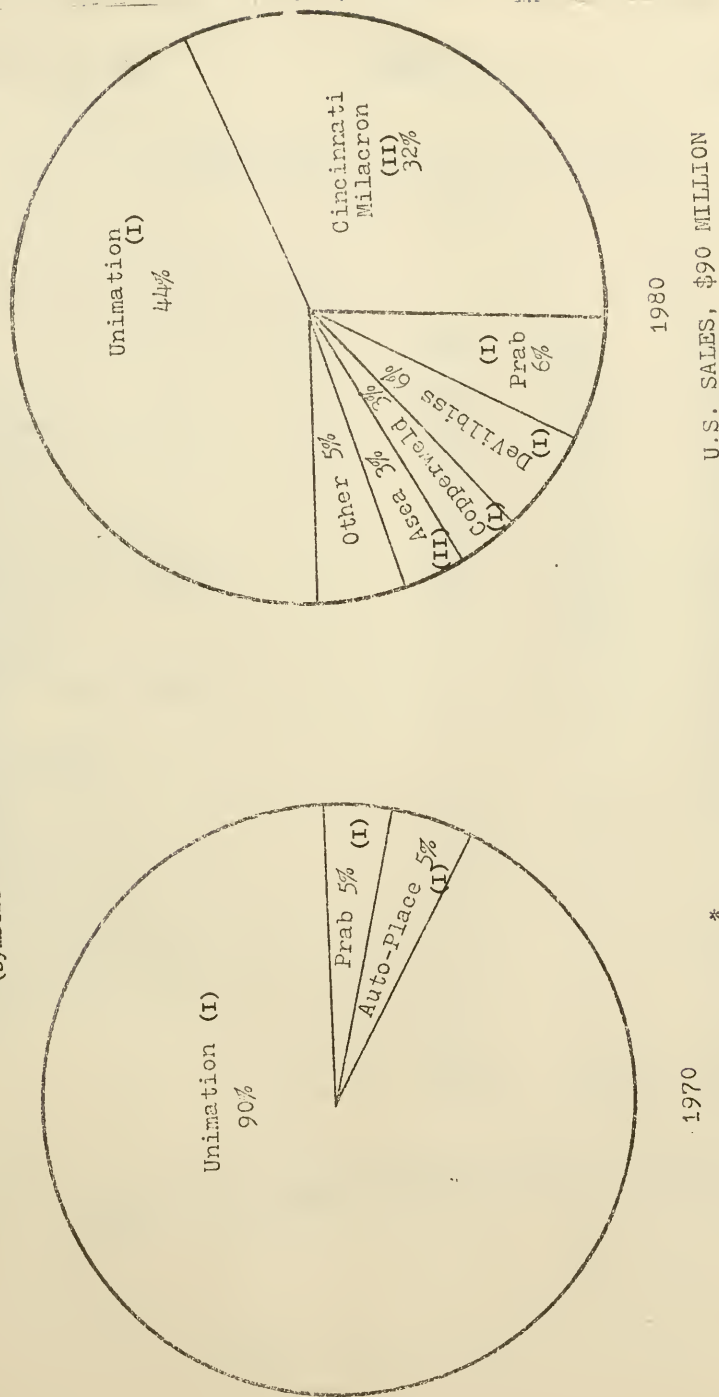
<u>Year</u>	<u>Firm</u>
1959	Condec Corp. (I) Planet Corp. (I)
1962	Unimation (I) A.M.F. (II) PaR Systems (I)
1969	Prab Conveyors, Inc. (I) Auto-Place (I)
1972	Devillbiss (I)
1973	Industrial Automates (I)
1974	Cincinnati Milacron (II) Mobot (I)
1979	ASEA (II) Binks (I) Nordson (I) Advanced Robotics Corp. (I)
1980	Thermwood (I) Automatix (I)
1982	General Electric (II) Westinghouse (II) I.B.M. (II) Bendix (II) General Motors-Fanuc (II) G.C.A. (I) Graco (I) Cybotech (I) Admiral Products (I) Control Automation (I) U.S. Robots (I)
1983	Textron (II) United Technologies (II) Nova Robotics (I) Intellelex (I) Machine Intelligence (I) Lloyd Tool and Mfg. (I)

SOURCE: David Schatz, The Strategic Evolution of the Robotics Industry, Unpublished Master's Thesis, Sloan School, MIT, May, 1983, p. 111; and modified by authors.

Figure 7

U.S. Robotics Industry Sales and Market Share

(Symbols in Parentheses Indicate Mode of Innovation)



SOURCE:

L. Conigliaro, Robotics Newsletter, Number 9,
Bache Halsey Stuart Shield, Inc., 1982; and
modified by authors.

*Estimated

Table 6

MARKET SHARE: U.S. BASED ROBOT VENDORS

(1980 - 1983)

	<u>1980</u>	<u>1981</u>	<u>1982</u>	<u>1983</u>
Unimation	44.4%	43.8%	32.1%	22.8%
Cincinnati Milacron	32.2%	32.2%	21.0%	16.2%
DeVilbiss	5.5%	4.2%	7.4%	6.7%
Asea Inc.	2.8%	5.8%	8.7%	7.2%
Prab Robots Inc.	6.1%	5.3%	4.2%	4.2%
Cybotech	-	-	4.9%	4.2%
Copperweld Robotics	3.3%	2.3%	2.3%	1.8%
Automatix	0.4%	1.9%	4.2%	7.6%
Advanced Robotics Corp.	1.9%	0.5%	3.5%	3.2%
Mordson	0.8%	1.6%	2.5%	2.5%
Thermwood	-	0.6%	1.6%	1.4%
Bendix	-	-	1.4%	2.3%
GCA Industrial Systems	-	-	1.0%	2.9%
IBM	-	-	0.7%	3.0%
GE	-	-	0.9%	1.1%
Westinghouse	-	-	0.4%	1.5%
U.S. Robots	-	-	0.6%	1.5%
Graco	-	-	0.6%	1.5%
Mobot	0.9%	0.4%	0.8%	0.8%
GM/Fanuc	-	-	1.5%	3.0%
American Robot	-	-	-	0.6%
Textron	-	-	-	0.3%
Nova Robotics	-	-	-	0.3%
Control Automat on	-	-	0.1%	0.3%
Machine Intelligence	-	-	-	1.1%
Intelledex	-	-	-	0.6%
Other	1.7%	1.3%	1.5%	1.7%
	100.0%	100.0%	100.0%	100.0%

SOURCE: L. Conigliaro, Robotics Newsletter, Number 9, Bache Halsey Stuart Shield, Inc., 1982.



Figure 8

INTERFIRM LINKAGES IN THE U.S. ROBOTICS INDUSTRY 1983

LICENSING AGREEMENTS

<u>Licensee</u>	<u>Licensor</u>
Kawasaki Heavy Ind.(Japan)	Unimation
FN Eurobotics(Belgium)	Unab
Den-Hag Mfg.(Canada)	"
Fukuda Machinery(Japan)	"
Birds(U.K.)	Charnwood
Cyclomatic Ind.	"
Diddle Graphics Co.	"
DeVilbiss	Tealifa(Norway)
Northern	Yamaha(Japan)
(Medical Equip. Co.)	"
Danlix	"
Automatic	Mitsubishi(Japan)
General Electric	"
Intertek	"
Grace	Holmug(Norway)
United Technologies	Mitsubishi(Norway)
AGI	Dainichi Kiki(Japan)
K.S.M.	Sanyo Seiki(Japan)
General Electric	B&B(Italy)
Westinghouse	Volkswagen(W.Germany)
"	Olivetti(Italy)
"	Mitsubishi Electric(Japan)
Eldred Tool and Mfg.	Komatsu(Japan)
	Jobs Robots(Italy)

JOINT VENTURES

<u>J.V.</u>	<u>Parents</u>
Unimation	Cowles, Pullman Corp.
GEF Robotics, Inc.	General Motors, Fanuc
Cybotek	Armstrong, Randsburg Industries
Smith Machine Intell.	Machine Intelligence, Yaskawa
Unico Robotics	Cowles Inc., Edon Finishing

BUYERS AND ACQUISITIONS

<u>Subsidiary</u>	<u>Parent</u>
Unimation	Westinghouse
DMR Systems	SCA
U.S. Robots	Square D Corp.
Copperweld Robotics (formerly Auto-Place)	Copperweld Corp.

SOURCE: David Schatz, The Strategic Evolution of the Robotics Industry, Unpublished Thesis, Alfred P. Sloan School of Management, May, 1983, p. 119.

national in character. The New Strategic Complexity has arrived in the U.S. robotics industry, perhaps just in time.

The growth of the Japanese robotics industry has been truly spectacular. In Figure 9, we see that by 1981 the Japanese were producing almost 23,000 units, compared to an estimated robot 5,500 robots in operation in the United States at that time. Or to use another example, of the 20,268 sophisticated industrial robots in commercial operation worldwide in 1979, 14,000 units were in use in Japan, 3,255 units in the U.S. and 3,013 units in Europe. Japan had over two-thirds of all the operating robots in the world.²¹ Looking again at Figure 9, we see another important characteristic: the takeoff came earlier in Japan than in the U.S., in the mid-1970s rather than the early 1980s. Robotics may be the first truly emerging technology-based industry in recent times that the Japanese have dominated from practically the beginning.

One important reason for Japan's success was the early development of a critical mass and great variety of technical and manufacturing capability for producing robots. Robot users are found in many sectors, as seen in Table 7. Table 7 shows that Japanese robot manufacturers range from small to medium to very large corporations. There are a large number of organizations in Japan involved in robot development, use, and marketing. Also, the robot industry possesses all modes of technological innovation. This is seen in Figure 10. Robot manufacturers are found in several industries.

One important aspect of the Japanese robotics industry is the key role of a few small Mode I enterprises. The leading example is Dainichi Kiko Co., Ltd.²² This company, founded in 1971 with capitalization of Y 1.5 million, is entrepreneurial, professional, and global in its outlook. It completed Japan's largest robot factory in 1982. Its president, Toshio Kohno, is 42. It has about 184 employees. From 1979 to 1983 sales grew from Y 0.8 million to about Y 14.0 billion. The firm produces a wide range of robots and sells



Fig. 1.—Percentage of the population in the United States who are under 16 years of age, 1900-1918.

Source: U. S. Bureau of Census, "The Population of the United States, 1918," p. 10.

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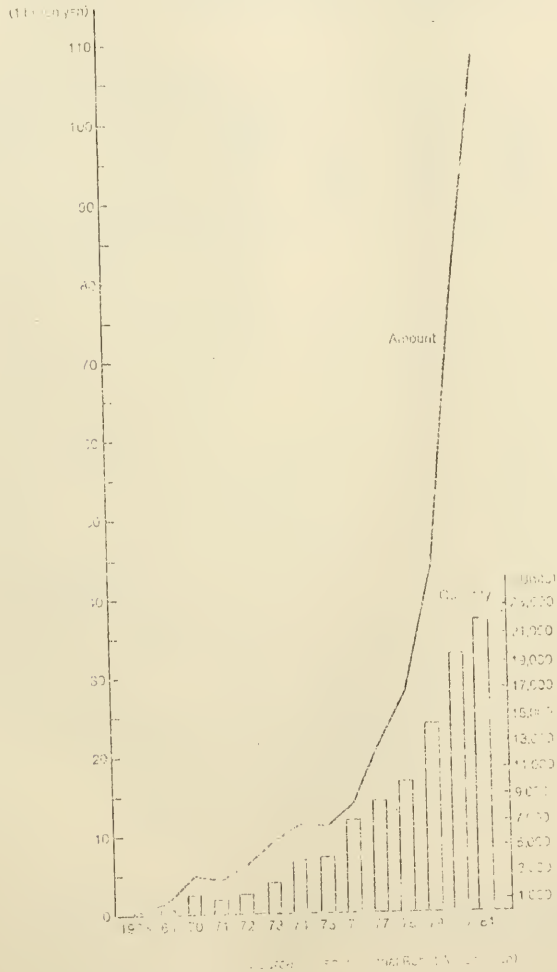
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Figure 9

Figure 1 Japanese production of industrial robots



SOURCE: The Long-Term Credit Bank of Japan, Inc., Japan's High Technology Industries, LTCB Research Special Issue, May, 1983, p. 8.

Table 7

Distribution of Japanese Robot Manufacturers

(Number of Firms in March, 1981)

No. of employees Capital	Less than 50	50 and over	500 and over	1,000 and over	5,000 and over	10,000 and over	Total
Less than Y1 million	2						2
Y1 m to Y10 m	21	5					26
Y10 m to Y100 m	10	23	2				35
Y100 m to Y500 m		9	5				14
Y500 m to Y1 billion		2	7	1			10
Y1 b to Y2 b		1	3	3			7
Y2 b to Y3 b			2	4			6
More than Y3 billion				20	11	18	49
Total	33	40	19	28	11	18	149

SOURCE: Kuni Sadamoto (ed.), Robots in the Japanese Economy (Tokyo: Survey Japan, 1981), pp. 30-31.

Figure 10

The Japanese Robot Industry, 1983

Classified by Modes of Innovation

Mode I	Dainichi Kiko Motoda Electronics
--------	-------------------------------------

Mode II	1) Makers of electrical appliances - Yaskawa Electric - Hitachi - Toshiba - NEC - Mitsubishi Electric - Okai Electric - Fuji Electric - Shinko Electric - Meidensha - Matsushita Electric Industrial 2) Makers of Machinery - Fanuc - Orii - Aida Engineering - Kayaba Industry - Nachi-Fujikoshi - Toyoda Machine Works - Komatsu Seisakusho - Tsubakimoto Machinery & Engineering - Tokyo Seiki - Toshiba Seiki - Sankyo Seiki 3) Makers of Transportation Machinery - Kawasaki Heavy Industry - Ishikawajima Harima Heavy Industry - Mitsubishi Heavy Industry - Mitsui Engineering & Shipbuilding - Shinmeiwa Ind. - Tokiko 4) Makers of iron and steel - Kobe Steel 5) Others - Pentel - Sailor Pen - Pilot Pen - Okamura
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Mode III	Standardization Project of Industrial Robots (1974-1978) Flexible Manufacturing System (1977-1983) Robot Research Program (1982 -)
----------	---

to small companies and large ones, such as Hitachi, Fujitsu, Matsushita Electric, and Mitsubishi Electric. Dainichi Kiko is now Japan's third largest robot manufacturer. It both uses internal R&D as well as outside sources. The company established partnerships with such firms as Cincinnati Milacron in 1982, NEC in 1983, and Yamazaki Iron Works in 1983 (Yamazaki is Japan's largest machine tool builder). Its orientation is global. In 1982, 50 percent of its products were exported. Dainichi Kiko is extremely sophisticated. Its strategy is based on entrepreneurship, professional analysis, global competition, and linkages.

Still, in Japan there are very few firms that specialize in producing only robots. Most robot firms come from other businesses.²³ Moreover, many of these firms are huge industrial enterprises with a large internal market to use as a base for robot development.²⁴ Also, about 70 percent of robot manufacturers have their own R&D laboratory and staff.²⁵ Of course, much has also been made of a supportive internal work climate with, for example, life-time employment and company unions.²⁶

Another aspect of robot development in Japan is the huge societal commitment to robot R&D. Fundamental research is being done at 85 universities and public institution across Japan.²⁷ MITI has also played a key role. It ended in the Spring of 1981 a 10-year project on information processing systems, with such participants as Toshiba, Fujitsu, Mitsubishi Electric, Hitachi, and NEC, which led to development of new sensor systems for robots. Another relevant government-sponsored project involved the development of "complex production systems with super-high-powered lasers".²⁸ Finally, the Japanese have quickly seen the need and advantages of establishing a number of strategic linkages, especially international ones, in the form of licensing and joint ventures. A list of such activities is given in Figure 11.

Figure 11

A. American Companies Importing or Licensing Japanese Robots

<u>United States (Importer or Licensee)</u>	<u>Japan (Exporter or Licensor)</u>
General Electric	Hitachi
Westinghouse	(Mitsubishi Electric Komatsu)
IBM	Sankyo Seiki
Hobart Bros.	Yaskawa
Automatix	Hitachi
Admiral Equipment	Yaskawa
GCA	Dai Nichi Kiko
GM (joint venture)	Fanuc
Advanced Robotics	Nachi Fujikoshi
Machine Intelligence Corp. (MIC)	Yaskawa Electric

B. Japanese Companies Licensing American Robots

<u>United States (Licensor)</u>	<u>Japan (Licensee)</u>
Unimation	Kawasaki
Prab Robots	Murata Machinery

SOURCE: Paul H. Aron, Testimony Before the Subcommittee on Investigations and Oversight of the Committee on Science and Technology, U.S. House, June 2, 1982, p. 3.

The contrast between the U.S. and Japanese robotics industries demonstrates once more the importance of multiple modes of technological innovation, the advent by the mid-1970s of effective Explicit Strategy in the Japanese case, where robot development first was often a key part of a general internal manufacturing strategy and then this experience with robots became the foundation for producing a product for an external market. Also, MITI very early targeted robotics as a key sector for national industrial policy. Finally, in Japan, the robotics industry by the mid-1970s reflected many of the aspects of the New Strategic Complexity, especially by exhibiting a growing and increasingly complex set of linkages, both domestic and international.

C. Biotechnology

Determining the structure and evolution of the emerging biotechnology industry is complicated, first of all, by the mixture of technologies and disciplines that comprise this industry. Biotechnology has been defined as "the use of living microorganisms, animal and plant cells, or their components, such as enzymes or membranes, to transform, synthesize, degrade or concentrate materials."²⁹ But it is still not clear that we can speak of a distinct "biotechnology industry", which involves the related areas of industrial microbiology, genetic engineering, and fermentation.

Another important dimension of complexity for biotechnology is the great diversity of potential uses and markets. At least four general market categories can be discerned: (1) health care and pharmaceuticals; (2) industrial chemicals; (3) agriculture; and (4) other (such as energy, mineral extraction, pollution control, and even biomolecular computers). Projections of the market for the entire biotechnology industry vary widely. For the year 2000, for example, they range from a low of \$14.6 billion to a high of \$500 billion.³⁰

The biotechnology industry almost from the start, has been a global industry with all modes of technological innovation in operation. This is seen on Figure 12. Countries known to have commercial biotechnology firms include: Belgium, Canada, Denmark, France, Italy, Japan, the Netherlands, Panama, Spain, Switzerland, United Kingdom, the United States, and West Germany. Biotechnology, in short, although in its early stages, is more strategically complex than was, for example, the early semiconductor industry or even the robotics industry.

In the U.S., Mode I and II biotechnology firms coexist and have established important linkages with one another. We will focus on three representative Mode I firms: Genentech, Cetus, and Biogen and three representative Mode II firms: DuPont, Monsanto, and Eli Lilly.

Genentech (GENetic ENGINEERING TEChnology), incorporated in California on April 7, 1976, was founded to develop commercial applications for rDNA technology.³¹ The firm's first milestone was the microbial expression of somatostatin, a brain hormone, in August 1977. A number of other breakthroughs have also been achieved. In many ways, Genentech appears to be a prototypical Mode I firm in focusing basically on a particular technology (rDNA) and maintaining high morale and loyalty. To retain scientists important equity and profit-sharing programs have been established.

But Genentech possesses significant non-Mode I characteristics as well. The firm is determined to be a total vertically integrated company that operates in the rDNA field and has a rather elaborate organization structure. Some departments relate to the flow of product development and other units are organized according to various substantive fields in the rDNA area. The company has five research departments and various functional departments, including process development, production, and marketing. Promising products in various areas, therefore, can be taken from initial development to diffusion in the marketplace.



FIGURE 12
Representative and Partial List of Institutions Participating in the Biotechnology Industry

Important modes of Technological Innovation	Home Countries of firms			
	United States	Japan	France	Other
MODE I				
Genentech		There are several small biotechnology firms in Japan, including Hayashibara		Biogen (Swiss & U.S.) Novo Industrie (Den.) Fortia (Sweden)
Cetus				
Collaborative Res.				
Genex				
Bethesda Res. Labs		Biochemical		
AgriGenetics		Wakunaga Pharmaceutical		
Hybritech				
Molecular Genetics				
Calgene, Amgen, Collagen				
Eugenics, Inten'l Plant Res. Inst.,				
Genetics Institute				
MODE II				
Du Pont, Campbell Soup		Sumitomo Chemical	Rhone-Poulenc	Grand Metropolitan (U.K.)
Monsanto, Johnson & Johnson		Daichi Seiyaku	Moët-Hennessy	Shell (U.K. & Neth.)
Eli Lilly		Mitsubishi Chemicals	Elf Aquitaine	B.P. (U.K.)
Fluor		Petrochemicals	BSN-Gervais-Danone	INCO (Can.)
Corning Glass		Kyowa Hakko Kogyo	Air Liquide	Hoffman - La Roche (Swiss)
Amoco		Toatsu Mitsui Chemicals	Roussel-Uclaf	Kabi Vitrum (Sweden)
Socal, Chevron		Asahi Chemical	Lafarge Coppee	Sandoz (Swiss)
Exxon		Ajinomoto		Ciba-Geigy (Swiss)
Nat. Distillers Corp.		Takeda Chemical		Imperial Chemicals (U.K.)
Upjohn, Pfizer, Seale, Merck		Daiichi Chemical		Basf (W. Ger.)
Mobil Oil, Allied, Koppers, Dennison, Bristol Myers, Dow Chemical, Phillips		Kirin Brewery		Hoechst (W. Ger.)
Phillips Petrol.		Mosuda Pharmaceutical		
Occidental Petroleum (Zoecon)		Nippon Kayaku		
Dekalb		Oji Paper		
AgResearch		Sanyo Chemical		
AKCO, GE		Suntory		
Union Carbide		Shionogi		
		The Green Cross		
MODE III				
Whitehead Inst. (MIT)		Bio-Technology Project (MIT)	Transgene Societe Lyonnaise [Institut Pasteur]	Celltech (U.K.) NEB (U.K.) British Technology Group (U.K.)

In addition, the firm has important financial linkages with large corporations and impressive financial resources for a Mode I firm. Large shareholders include Fluor, Monsanto, and Corning Glass. About 1.8 percent of the firm is owned by a group of eight Japanese financial and educational institutions. In addition, on October 14, 1980, Genentech raised \$36.5 million in a public issue of 1,100,000 shares at \$35 per share. In 1981, Genentech's revenues were over \$21 million with about \$.5 million in net income (\$.06/share). Assets were approximately \$66 million.

Genentech's strategy is impressive and sophisticated. Its top management is professional. The firm is involved in a number of research contracts for several companies, including Fluor, Hoffmann-La Roche, A.B. Kabi, Eli Lilly, Monsanto, Lubrizol, I.P.R.I., Vega Bio Chemicals, Corning Glass Works, Sumitomo Chemical, and Daiichi Seiyaku. Genentech is also working on about thirty proprietary projects. In terms of product development, the firm has focused its core business on the human health care field. But Genentech is also laying the foundations for entry into other areas, such as animal growth, hormones, and industrial enzymes. It is developing an increasingly large set of proprietary products and processes that, it hopes, will act as barriers to entry. Particularly significant is the firm's strategic use of research agreements, licensing, and joint ventures in order to enter the market quickly and to gain production and marketing expertise. Also the strategic linkages with outsiders perhaps preempts some of the competition in the short term and allows Genentech time to establish itself as a secure full-line biotechnology company. Its strategic sense of timing is also illustrated by the way it has focused first on high-margin, low-volume pharmaceutical products in which it has developed a particular competence. The firm has also obviously been successful in obtaining its financing needs without exhausting any single source of capital. Genentech has also established a leadership position at least

partially by particularly good management of its public relations. Finally, the firm has paid careful attention to its management structure and human resources, balancing a sound strategy with a commitment to recruit and keep high-caliber scientists.

Cetus presents an interesting contrast to Genentech.³² Cetus has a strong scientific orientation and is more purely technology driven. For example, the firm has an active and diverse 30-member scientific advisory board. Also, the company has a rather unique method for establishing entrepreneurial 60-percent-owned subsidiaries in order to keep creative and ambitious scientists. Consequently, Cetus has had a broad portfolio of biotechnology business activities and a more loosely structured and decentralized organization. Moreover, although Cetus' strategy has thus far appeared less clear than that of Genentech, the firm possesses a high level of morale and loyalty from its employees and may also be more opportunistic than Genentech.

Although more purely Mode I than Genentech, Cetus (like Genentech) has close financial linkages with large corporations, such as Amoco, Socal, and the National Distillers and Chemical Corporation. Also, seven months after Genentech's public issue, in March 1981, Cetus raised \$107.2 million through a public offering, the largest in U.S. corporate history. Cetus, also like Genentech, has a significant number of research agreements with firms. But, unlike Genetech, Cetus is much more dependent on research agreements with its equity partners. Also, Cetus' projects have been much less concentrated in terms of field. Cetus' activities are in health care, chemicals, food, agriculture, and energy. The company's competitive strategy also calls for the use of patented, as well as reliance on unpatented, proprietary knowledge. In addition, Cetus has not aimed to be a totally integrated biotechnology firm and does not generally aspire to be a large-scale producer. Instead, it has

focused on many and diverse R&D efforts and it has established joint efforts with its equity partners for larger-scale activities. This strategic choice --not to focus, say, on health care-- to develop genetic engineering applications for many industries, particularly in the chemical-process and energy industries, is ostensibly in order to avoid the areas of most intense competition. But it may also be due to the influence of its major equity holders.

Cetus has considerable strengths, including possessing proprietary technologies, knowledge, and experience due to being an early participant in the industry, successfully obtaining a massive amount of funding from a public offering and also strong equity partners, and having vigorous high-level technological champions. But a key area of vulnerability, until very recently, may have been an apparent inability or lack of willingness to focus. Perhaps Cetus has been in too many areas; rather than being merely opportunistic, it may have been spread too thinly.

Cetus seems to have recognized this weakness. In January, 1983 it lured a line-oriented president away from Biogen. Also, in the summer of 1982 it initiated a reorganization that reduced its research staff and narrowed the scope of its research efforts.

Mode I biotechnology firms are not only found in the United States. Biogen N.A., formed in May 1978 as a Netherlands Antilles corporation, has a major operating subsidiary in Geneva, Switzerland and a more recently formed subsidiary in Cambridge, Massachusetts.³³ Biogen illustrates the complex international character of even Mode I firms at the very beginning of this industry.

Like Cetus, Biogen has a broad range of technological expertise. But, like Genentech, it also aims to be a fully integrated manufacturer. The firm claims to have broad scientific expertise in such areas as mammalian, bacterial, yeast, and fungal genetics, rDNA technology, enzymology, nucleic

acid and protein chemistry, microbial physiology, cell culture, immunology, and fermentation technology.

Biogen, like Cetus and Genentech, has also been successful in raising substantial capital, though not yet through public offerings. The original investors provided an initial capitalization of \$750,000. In 1979, Schering-Plough invested \$8 million for 16 percent of the company, giving Biogen a valuation of \$50 million at the time. By 1981, without going public, Biogen had raised nearly \$40 million in capital, including some \$20 million from Monsanto. In October, 1981, an unspecified private placement was made with new, unnamed institutional investors. Between them, Schering-Plough, Monsanto, Grand Metropolitan, and the International Nickel Company (INCO) own just under 50 percent of the company's shares. The rest is held by the original investors, employees, and the new institutional investors. In July, 1981, the New Standard (London) valued Biogen at \$425 million (at a time when the company was rumored about to go public). In February, 1983 Biogen filed a preliminary prospectus in order to raise at least \$55 million through a public offering.

All four of Biogen's major corporate equity holders have some R&D arrangement with the company. Although, as also discussed with regard to Cetus, there could be some disadvantages in such a situation, the four Biogen equity holders are relatively diverse and can provide Biogen with marketing partners in four areas: INCO in metals and mining, Schering-Plough in pharmaceuticals, Monsanto in chemicals, and Grand Metropolitan in food processing. Moreover, Biogen has significant relations with other firms.

All three representative Mode I firms, Biogen, Genentech, and Cetus, exhibit significant similarities and permit some important generalizations to be offered, some of which may also apply to some of the 150 to 300 other Mode I biotechnology firms as well.³⁴ The three firms that we reviewed have all established strong financial and R&D linkages with larger corporations. These

relationships are often multinational in character. Moreover, all three firms represent the collaboration of the scientist and the venture capitalist. These companies all exhibit some degree of Explicit Strategy; more so, for example, than the earlier Mode I semiconductor firms. They also have more formal and more coordinated linkages with outside institutions. But there are significant differences between these firms. Biogen, in one sense, is a mixture of Genentech and Cetus. Like Cetus, it is diverse with a broad scientific base. Also, like Cetus, its strategy is less focused and more opportunistic than that of Genentech. But, like Genentech, Biogen plans to be a fully integrated manufacturer of biotechnology products. Also, Biogen has the unique characteristic, especially for a Mode I firm, of being from birth multinational.

Strategic complexity in the U.S. biotechnology industry extends to the Mode II firm. From practically the beginning the large Mode II corporation has been significantly involved with developing and participating in the biotechnology. The active, early, and strategic involvement of large, diversified corporations is a key feature of this industry. Three representative Mode II corporations will be briefly discussed.

Du Pont is basically taking an inhouse and large-scale approach to biotechnology R&D.³⁵ The firm wants life-sciences R&D projects that will likely have "multiple innovations that meet fundamental human needs and that are compatible with the company's technical and marketing capabilities." Du Pont is doing research in at least four basic areas: 1) food production (Du Pont is a major supplier of crop-protection chemicals); 2) health care (diagnosis and treatment of diseases); 3) renewable resources (using bacteria and fungi in fermentation processes that will employ renewable resources, such as sugar, starch, and cellulose, to generate feedstock chemicals); and 4) interferon research. In applying its research to chemical process improvements, the company is hoping to improve quality or to reduce costs for high volume products.

Du Pont has made an large commitment to biotechnology. It announced in July, 1981 that it planned to construct an \$85-million research complex near Wilmington, Delaware for health science research, which will have a staff of 700. Du Pont is also adding 100,000 square feet of space to its existing plant-sciences laboratories. With these new facilities, Du Pont will expand its research in molecular genetics, immunology, neurology, cardiology, gerontology, plant biology, plant pathology, and antomology.

A key feature of Du Pont's approach to biotechnology is its heavy internal-development orientation (with the exception of its relationships with universities and university researchers). Only as a last resort will the company have other firms, such as Genentech, Cetus, or Biogen, develop its innovations.

Obviously, Du Pont's strategy strengthens its control of development, maximizes the likelihood of maintaining proprietary ownership of new processes and products (thereby creating barriers to entry), facilitates the incorporation of innovations in existing processes or products, and eliminates potential conflicts of interest among equity partners.

Monsanto, the second largest U.S. chemical company, offers a contrasting strategic approach for Mode II participation in biotechnology.³⁶ The firm's active involvement in biotechnology is part of an overall radical strategic transformation. The main strategic goal of Monsanto is to move away from petrochemicals and into special products and high technology areas. Although, like Du Pont, Monsanto has a long-term commitment to biotechnology and is actively developing an internal capability, it is also heavily involved in biotechnology through external investments and research contracts with various Mode I biotechnology firms. Monsanto has equity interests in Genentech (1.6 percent), Genex (10 percent), Biogen (20 percent), and Collagen (23 percent).

Monsanto is also developing personnel policies to keep key scientists. It encourages the publication of scientific papers by its scientists, provides career incentives, has a "Fellows Program", and gives a \$25,000- and a \$50,000--award for significant scientific contributions.

Monsanto probably has the most complex Mode II strategy, in terms of working in a diverse range of fields (such as agriculture, health care, pollution control, and chemicals), making a commitment both to a strong internal R&D capability and to effective linkages with specialized biotechnology firms, and developing a worldwide competitive strategic posture that involves relative short-term R&D activity (using the firm and outsiders) and a growing accumulation of permanent knowhow. It also has an extensive university funding effort, and in June, 1982 gave the Washington University Medical School \$23.5 million for biotechnology research. It even has entered a biotechnology joint venture with a consortium of British universities.

Eli Lilly, a large U.S. pharmaceutical company, has about 80 to 90 percent of the U.S. animal-derived-insulin market (which is about 50 percent of world sales).³⁷ Like Du Pont and Monsanto, Lilly has made a long-term commitment to biotechnology. Lilly is also planning the construction of a \$60-million biomedical research center to focus on the frontier areas of pharmaceutical research. The center should be completed in 1984. The company's R&D expenditures increased 17 percent from 1980 to 1981, from \$200.7 million to \$234.8 million. But for the short term Lilly has a more focused biotechnology product and process strategy that either Du Pont or Monsanto. Lilly has specifically concentrated on producing human insulin using Genentech's rDNA technology under an agreement with that firm. Like Monsanto but not Du Pont, it has formed significant linkages with the more specialized Mode I biotechnology companies. Lilly plans to use a near-term, focused foundation as a technological and financial base on which to create a

broader and permanent expertise in biotechnology. For the longer term, Lilly is also conducting research on agricultural applications. Along with its internal work and the arrangements with Genentech, Lilly also has research agreements with the International Plant Research Institute on photosynthesis and on the development of salt- and drought-resistant wheat.

As seen in the cases of Du Pont, Monsanto, and Lilly, although each corporation has a somewhat different strategic approach for involvement in the biotechnology industry, together they (like the Mode I U.S. biotechnology firms) demonstrate the inherent variety and complexity that now may characterize technological innovation and strategy for today's emerging, technology-based industries. For Mode II U.S. biotechnology firms, there are specific differences regarding the initial strategic choice between focus and breadth (with Lilly being the most focused and Du Pont and Monsanto attempting to be very broad at the very beginning; Lilly, however, plans to be broad eventually). In addition, there is conceptually a strategic choice in developing technology between solely building an internal capability or depending mostly on external firms through research agreements and/or equity positions. (Du Pont has basically chosen to develop its biotechnology inhouse; Lilly uses outside biotechnology firms like Genentech; and Monsanto is attempting to do both). Finally, there is a critical personnel issue ---closely tied to the key choice of inhouse or contracted R&D--- with which both Du Pont and Monsanto are wrestling: how can large Mode II corporations keep the "best" technical people in an emerging high-technology industry? The attraction of independence, equity, and being an entrepreneur exists, and it is still unclear whether the motivational techniques being used, for example, by Monsanto to reward and keep critical scientists will be successful. Mode II U.S. firms may have sound, well developed Explicit Strategies. But they also need effective Implicit attributes as well.

1880-1881. 1882-1883. 1884-1885.

1886-1887. 1888-1889. 1890-1891.

1892-1893. 1894-1895. 1896-1897.

1898-1899. 1900-1901. 1902-1903.

1904-1905. 1906-1907. 1908-1909.

1910-1911. 1912-1913. 1914-1915.

1916-1917. 1918-1919. 1920-1921.

1922-1923. 1924-1925. 1926-1927.

1928-1929. 1930-1931. 1932-1933.

1934-1935.

1936-1937.

1938-1939.

1940-1941. 1942-1943. 1944-1945.

1946-1947. 1948-1949. 1950-1951.

1952-1953. 1954-1955. 1956-1957.

1958-1959. 1960-1961. 1962-1963.

1964-1965. 1966-1967. 1968-1969.

1970-1971. 1972-1973. 1974-1975.

1976-1977. 1978-1979. 1980-1981.

1982-1983. 1984-1985. 1986-1987.

1988-1989. 1990-1991. 1992-1993.

1994-1995. 1996-1997. 1998-1999.

2000-2001. 2002-2003. 2004-2005.

2006-2007. 2008-2009. 2010-2011.

2012-2013. 2014-2015. 2016-2017.

2018-2019. 2020-2021. 2022-2023.

2024-2025. 2026-2027. 2028-2029.

2030-2031. 2032-2033. 2034-2035.

2036-2037. 2038-2039. 2040-2041.

2042-2043. 2044-2045. 2046-2047.

In Japan, the commitment to biotechnology is also strong, broad, energetic, and increasingly multifaceted.³⁸ Perhaps over a hundred Japanese firms are now involved in biotechnology in some way, including the following: Ajinomoto, Daichi Seiyaku, The Green Cross, Kanegafuchi Chemical, Kirin Brewery, Kyowa Hakko Kogyo, Meiji Seika, Mitsubishi Chemical, Mitsui Toatsu Chemical, Mochida Pharmaceutical, Shionogi, Sumitomo Chemical, Takedo Chemical, Tanabe Seiyaku, and Toray Industries.

A partial example of a Japanese Mode I biotechnology company is Hayashibara Biochemical Laboratories, which is one of the ten companies in the Hayashibara Group.³⁹ The Group has about 350 employees and sales of Y28 billion in 1982. The Group's president, Ken Hayashibara, is 41. Hayashibara Biochemical Laboratories has 110 employees (100 researchers) and a 1982 R&D expenditure of Y2 billion, which makes this firm the third or fourth largest private-sector biotechnology R&D operation in Japan. Hayashibara is the leading company in the world for the production of interferon alpha using human cell implantation in hamsters. The R&D activities at Hayashibara Biochemical Laboratories are fully supported by the Group. The Group's investment in the Fujisaki Institute, the Laboratories' new main laboratory, amounted to nearly Y3 billion.

Hayashibara has no R&D budget system. Researchers, the president says, can purchase any instrument and they do not have to worry if their programs produce no products for as long as about ten years. Mr. Hayashibara also believes that small is beautiful: "One of my policies for years is to keep the [Group's] payroll at no more than about 350 employees. People of the older generation think that expansion is the main goal of a company. But to be innovative, to create new things, it helps to not grow too big." Hayashibara's strategy is clear and focused. The Group does not want to be a fully-integrated company. It wants to be the biotech engineering company with

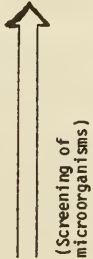
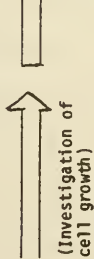
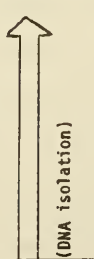
some capabilities in the production of food ingredients, its traditional products. The company wants to license technologies and receive royalties in the biochemical industry. The Group seeks to establish linkages with many Mode II companies mainly for joint development and commercialization. It now has licensing or R&D cooperative agreements with Mochida Pharmaceutical, Otsuka Pharmaceutical, Mitsubishi, MBB in West Germany, and the Inseim Pastol Laboratory in France.

Under the auspices of the Ministry of International Trade and Industry (MITI), a \$113-million Biotechnology Project has been established in which several major Japanese firms have formed a research association and are cooperating to develop technological expertise in rDNA technology, bioreactors, and mass cultures, as seen on Figure 13. In addition, many major Japanese firms have substantial biotechnology R&D efforts of their own. For example, Mitsubishi Chemical's biotechnology research unit has 150 basic researchers. Kyowa Hakko is establishing a "life sciences institute" (along side its ongoing biotechnology R&D facility) where foreign experts will be invited to work. Most Japanese biotechnology firms, about 84 percent according to a recent MITI survey, also have significant cooperative R&D relationships with other companies, universities, or national institutes.⁴⁰ Moreover, the Japanese expect and desire an increasing number of linkages with foreign biotechnology firms, especially American ones.⁴¹ This new open attitude toward linkages and interorganization cooperation is a relatively new development for Japanese technology strategy.

It is in biotechnology, even more than in robotics, where the "New Strategic Complexity" is most apparent. Linkages are being established between Mode I & II firms in the U.S. and between Mode I, Mode II, and Mode III endeavors in Japan. Moreover, U.S. & Japanese firms are forming a variety of interlocking relationships. They are also entering into important research, licensing, and marketing agreements with U.S. and European firms in order to establish and maintain shares of world leadership in the emerging biotechnology



Figure 13
 MITI Research & Development Project of Basic Technology
 for Future Industries
 -Biotechnology R&D Project-

Fiscal Technology	1981	82	83	84	85	86	87	88	89	90	Participating Enterprises
Bioreactor (about ¥ 11 billion)	 (Screening of microorganisms) (Determination of the process) (Test production and evaluation)										Kao Soap Co. Daicel Chemical Industries. Denki Kagaku Kogyo K.K., Mitsui Petrochemical Industries, Mitsubishi Gas Chemical Co., Mitsubishi Chemical Industries
Mass cell culture (about ¥ 5 billion)	 (Investigation of cell growth) (Development of optimum culture medium) (Establishment of a mass culture method)										Asahi Chemical Industry Co., Ajinomoto Co., Kyowa Hakkō Kogyo Co., Takeda Chemical Industries, Toyo Jozo Co.
Recombinant DNA (about ¥ 10 billion)	 (DNA isolation) (DNA recombination) (Establishment of an isolation and refining process)										Sumitomo Chemical Co., Mitsui Toatsu Chemicals, Mitsubishi-Kasei Institute of Life Science

NOTE: The amounts in parentheses indicate subsidies from MITI.

SOURCE: Long-Term Credit Bank of Japan, Ltd., Japan's High Technology Industries, LTCB Research Special Issue, May, 1983, p. 39.

sector. A few Japanese firms and other institutions also have equity in American biotechnology firms. This trend is seen in Figure 14.

V. Conclusion

Our brief comparative discussion of the semiconductor, robotics, and biotechnology industries in the U.S. and Japan offers a number of lessons for the theory and practice of corporate strategy in modern technology-based sectors. One of our most important findings concerns the great variety of kinds of technologically innovative activity that now takes place in each of these industries. All Modes of technological innovation are operating, as seen in Figure 15.

But the portfolios of these activities are not the same in the two nations (although they are roughly the same in each country for each of the three industries). In the U.S. activity is centered in the small high technology firm (Mode I) and in the large multi-product/market corporation (Mode II). This is true for the oldest technology-based sector studied, semiconductors, as well as for the newer ones, robotics and biotechnology.

The importance of both Mode I and Mode II activity today in emerging industries in the U.S. is particularly significant. The pattern is very different than, say, for the rise of semiconductors in the 1950s and 1960s. At that time, the early semiconductor industry had a highly fragmented and disconnected industrial ecology. The players in each of the modes were formally separate. The transactions across organizational boundaries were largely buy-and-sell ones or involved the movement of key people. Strategies were Implicit, focusing especially on markets, quick and flexible adaptability, and autonomy. The long-term focus that did exist in some firms was limited primarily to investment in R&D. Government action, although absolutely essential, was indirect and limited especially to the key function of being an

Figure 14

Relationships Between U.S. and Japanese Biochemical Companies

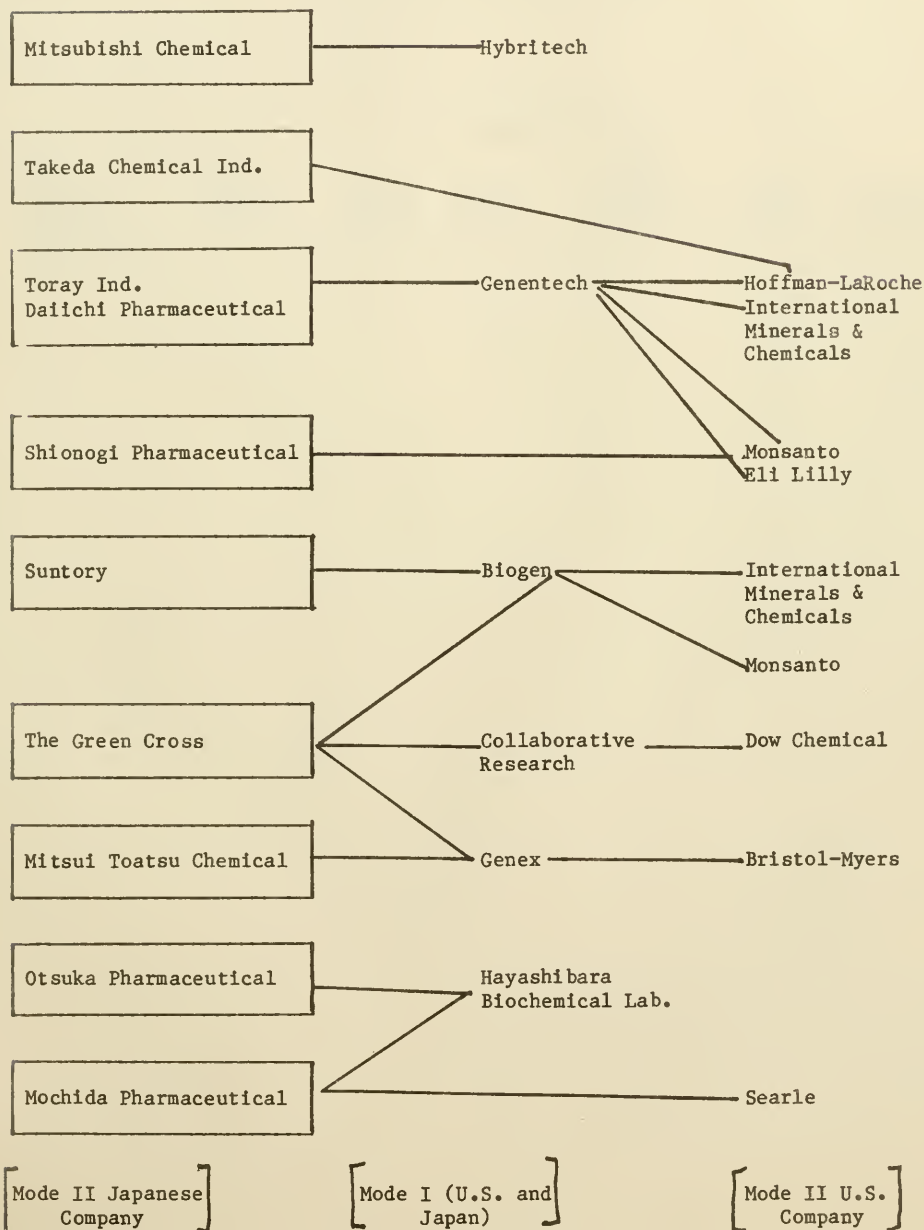




Figure 15

Modes of Technological Innovation,
by Industry and Country, 1983

Modes of Techno- logical Innovation	<u>Industry/Country</u>					
	Semi- conductors (U.S.)	Robots (U.S.)	Biotech. (U.S.)	Semi- conductors (Japan)	Robots (Japan)	Biotech. (Japan)
I	X	X	X		X	X
II	X	X	X	X	X	X
III				X	X	X

enthusiastic and large early market. The whole technology-strategy relationship was highly disjointed. Formal linkages and comprehensive long-term strategic action were rare.

If we turn to the present and the early stages of potentially equally revolutionary industries, such as robotics and biotechnology, a very different pattern emerges. There is still great variety in terms of technological innovative activity. But now many more of the institutional participants are acting strategically along a broad front, not in just in terms of R&D investment. Several Mode I firms have highly professional managers. Moreover, Mode I firms have established strong, close, and formal linkages with larger corporations. Unlike the Mode I U.S. firm of the early semiconductor industry, in robotics and biotechnology the small firm often manifests a highly strategic orientation.

Similarly, the Mode II U.S. firm in all three industries today acts in a very different fashion than it did during the rise of semiconductors. Most important, the established large firms have generally recognized new technologies as strategically important. Unlike Sylvania or Raytheon in the early semiconductor industry, the established and relevant Mode II firms today are not ignoring semiconductors, robots, or biotechnology. They generally view these sectors as key strategic business areas. They do not want to be left behind and, indeed, appear almost hyper-aware of the potential importance of new technology for their long-term future. Consciously or unconsciously the stark failures and equally dramatic successes in earlier technology-based industries, like semiconductors, have had a significant impact on current Mode II strategic behavior. U.S. large firms are attempting at least to keep pace with development of technology and business opportunities through both inhouse and external efforts. Such firms exhibit a purposeful, forward-oriented, and Explicit strategic-management behavior pattern with regard to technology that did not exist often in the early semiconductor industry.

In Japan, we also see tremendous and growing variety in terms of kinds of innovative activity taking place. The most important difference, of course, is the key role of the government --Mode III-- in shaping basic R&D activity in the three industries studied. The government in Japan is an active strategist, though by no means the sole or even the most important strategic decision maker. In fact, there seems to be an evolutionary trend in Japan to broaden and balance its portfolio technological innovative activity. In semiconductors, especially with the VLSI Project, the government's role was paramount. In robotics, a few small high-technology firms, several large corporations, and the government and other institutions share R&D activity, with the center of gravity shifting to the large corporations. Finally, in the newest industry, biotechnology, the set of technological innovative efforts is much more balanced between Modes I, II, and III. Japan has developed a critical mass in terms of variety and number of kinds of R&D efforts taking place.

Another key feature of technology-based sectors in both the U.S. and Japan is their strongly linked nature. As we have seen in robotics and especially biotechnology in both countries, there are strong and formal connections between the firms in these sectors. And the linkages are often global. Therefore, there is conceptually a growing choice between competition and cooperation in terms of developing a technology-based business. The management of linkages is a key part of the modern strategy-technology relationship.

The growing complexity, the multifaceted array of linkages, and the huge task of dealing with concurrent variety of innovative activities present us with perhaps the key tradeoff of modern corporate strategy: balancing Implicit and Explicit perspectives. Long-term strategic planning and complicated resource allocation and product/market categories are essential for managing

the diverse systems of activities that have been established. However, we are in danger of losing the benefits of Implicit Strategy, such as entrepreneurial commitment, quick reaction and adaptation to changes, individual creativity, ease of communication, and a focus on implementation.

Large firms are struggling with this primary tradeoff. But it is clear that we cannot return to an era of complete autonomy, decentralization, and pure, basic "good management". The New Strategic Complexity with all its strong linkages is a permanent and growing fixture on the global competitive landscape, at least for technology-based sectors. Rather, the answers lie accepting the need for both Implicit and Explicit Strategies and, as many firms are now doing, developing a number of approaches for incorporating both perspectives into technology-strategy decision making.

We now see that our examination of technology-based sectors has highlighted perhaps the most fundamental challenge facing modern corporate strategy both in the U.S. and Japan: performing adequate strategic analysis for usefully understanding all the key variables that make up the New Strategic Complexity while effectively implementing strategic actions unencumbered by an overly burdensome analytical overhead and structure. Our analysis tells us that, given hard work and effective mechanisms, sound strategic analysis and strategic action can coexist. But being effective at both is not easy and requires on-going attention and commitment. This is true in both the U.S. and Japan.

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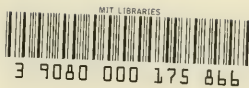
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